Performance of P-type Microstrip Detectors Irradiated to 7.5×10^{15} p/cm^2

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Abstract

Exploiting the advantages of reading out segmented silicon from the n-side, we have produced test detectors with LHC pitch but 1cm length strips which even after proton irradiation at the CERN PS to 7.5×10^{15} cm^2 show signal to noise of 7:1 with LHC speed electronics. This dose exceeds by a factor of 2 that required for a replacement of the ATLAS semiconductor tracker to cope with an upgrade of the LHC to a Super-LHC with 10 times greater luminosity. These detectors were processed on p-type starting material of resistivity ~ 2 kΩcm and, unlike n-in-n designs, only required single-sided processing. Such technology should therefore provide a relatively inexpensive route to replacing the central tracking at both ATLAS and CMS for Super-LHC. The shorter strip length is required since even with n-side readout, at these extreme doses only 30% of the non-irradiated signal is seen. However, this 7000e signal (in 280 µm thick sensors) seen after such high doses is competitive with more exotic substrates and the hit density expected at a Super-LHC would require a scaling down of the sense element area by a factor of 10 to retain an occupancy of less than 1% in the layers of the central tracker. We therefore propose such a 'stripsel' design as a possible low cost and easily implemented route to achieving the requirements for very high luminosity tracking at an upgraded LHC.

Summary

Polysilicon biased, capactively coupled 80µm pitch micro-strip detectors to ATLAS specifications were designed at the University of Liverpool and processed by the Centro Nacional de Microelectronica (CNM) Barcelona on 2kΩcm p-type silicon. These detectors were subsequently irradiated in the CERN PS to doses of 1.1×10^{15}p/cm^2, 3×10^{15}p/cm^2 and of 7.5×10^{15}p/cm^2. These test detectors had only 1cm strip length although we have previously demonstrated large area ATLAS deigned p-type detectors processed by Micron Semiconductor UK Ltd. The small area both facilitated achieving large uniform doses without scanning the devices in the PS beam and provides a testbed for one possible sensor strategy for the Super-LHC, that of short strips or 'stripsels'.

Figure 1 shows that for 1cm strips, the signal/noise values obtained at reasonable voltage with a ^{106}Ru β-source are very acceptable for such p-type single-sided detectors. Even sensors of full 12cm length to this design should retain a signal/noise >10 after this dose, suggesting use of this technology and current style module designs could be possible for the higher radii. However, as figure 2 shows, for the highest doses down to the inner radii equipped currently with microstrips, adequate signal/noise does require shorter sense elements as, compared with the signal for a non-irradiated sensor, only 30% of the charge is collected even at 900V. Nevertheless, it is also found that the noise is independent of the sensor dose (the electronics is unirradiated) leading to the possibility of adequate tracking with shorter strips even after 10 years of Super-LHC operation.

Since the proposed technology is single-sided, and large area devices have been proven by us previously with a mainstream commercial supplier, we believe that this represents an affordable solution to tracking at the Super-LHC. Furthermore, since many of the largest manufactures dislike the added complication of double-sided processing required of n-in-n technology, such as used in the General Purposed Detector pixel detectors and LHCb's VeLo, this represents an option that should be compatible with processing at most suppliers. Finally, it should be noted that although the devices at the medium dose was oxygenated, the others are not suggesting that this additional processing step does not bring such major advantages for p-type detectors.

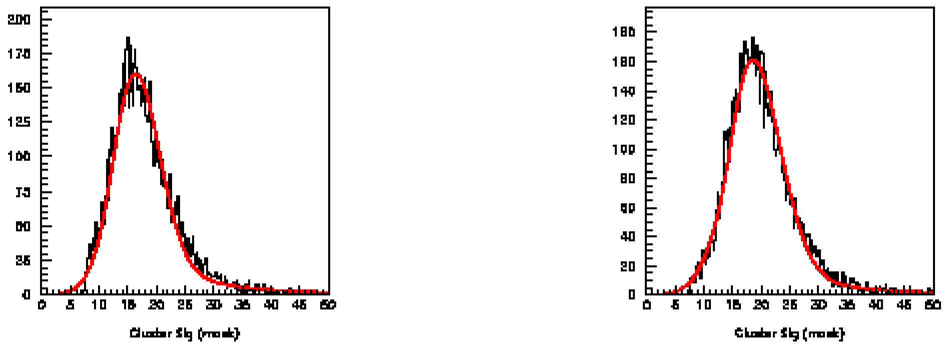

Figure 1. Cluster Significance After 1.1×10^{15}p/cm^2 for 400V and 800V

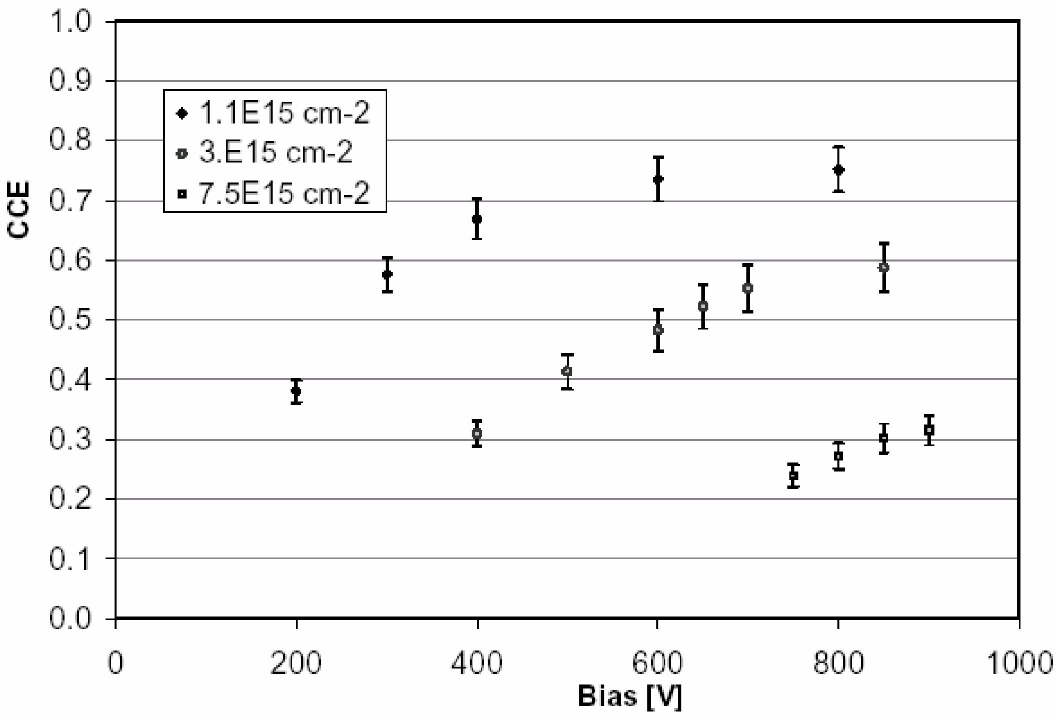

Figure 2 Charge Collection Efficiency vs Bias Voltage